Exploring Stratospheric Implementation Issues: Experiments with the GMI CTM and the Goddard CTM

GMI Science Team Meeting

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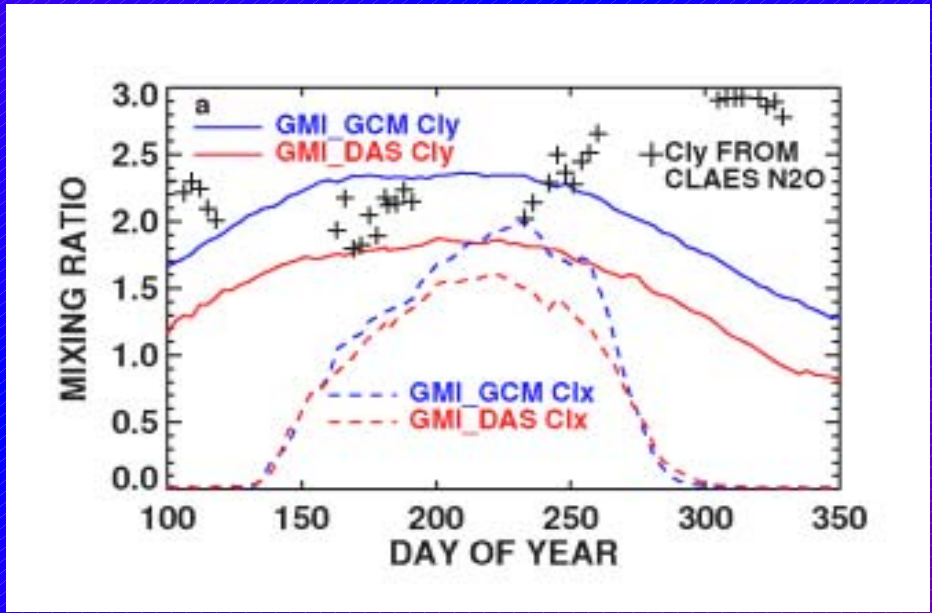
Motivation: Problems in the WMO Trend Runs

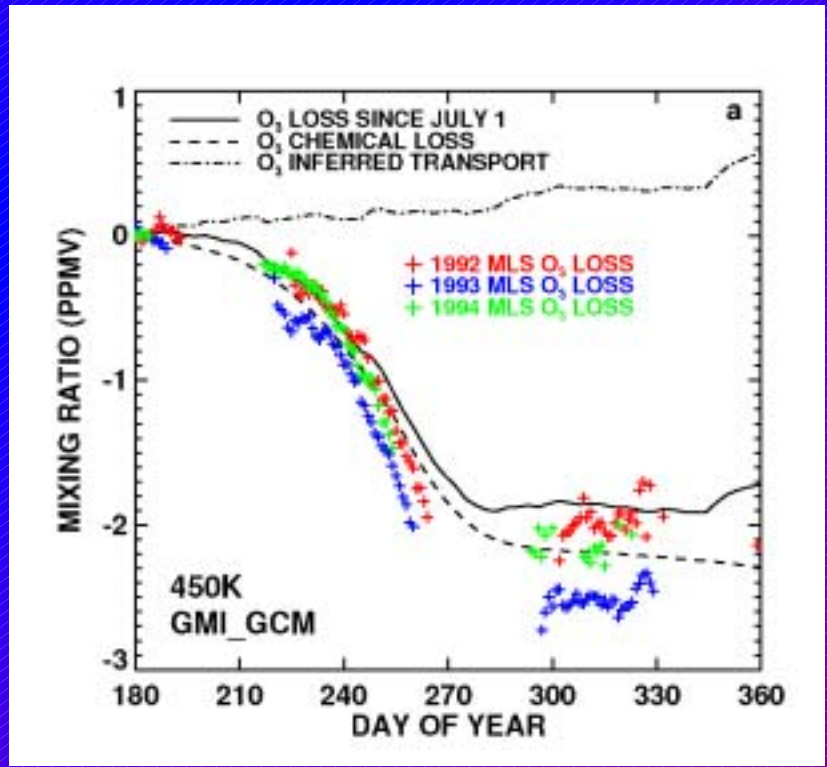
- *Considine et al.* [2004] showed high ClO and Cl_y levels not maintained into October.



- Antarctic vortex 'mixing test' using HALOE CH_4 [*Strahan and Douglass*, 2004] showed that 4x5° GMI vortex does not create a barrier to mixing with midlatitudes.

A significant problem: GMI Trend Runs don't lose enough O_3 in the LS vortex

- Without high Cl_x in Sept and Oct, Antarctic O_3 loss is slower and ends prematurely (Considine et al., 2004).
- We would have more confidence in an ozone recovery prediction if the model vortex were more realistic.



GMI-CTM: Horizontal Resolution Sensitivity

- 1 year simulations of GMI stratospheric model with full chemistry
- 2x2.5^{o} and 4x5^{o} horizontal resolutions
- Same 28 vertical levels (lid at 0.4 mb)
- Year 2029 of the WMO trend experiments
- 12 species saved

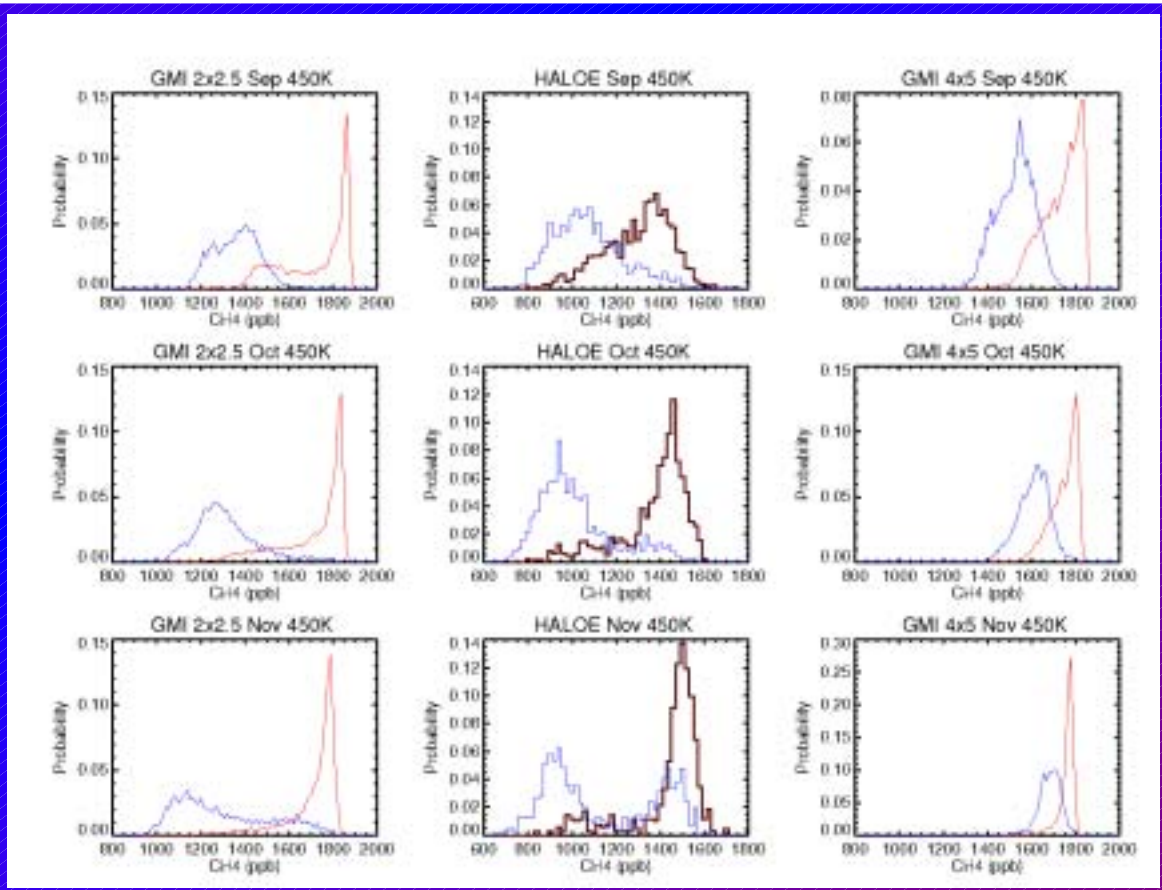
Horizontal Sensitivity: Antarctic Vortex Edge

60-80°S PDF in blue 40-60°S PDF in red

Results:

2x2.5° resolution shows better agreement with HALOE CH_4.

The 2x2.5° vortex has a more realistic mixing barrier.



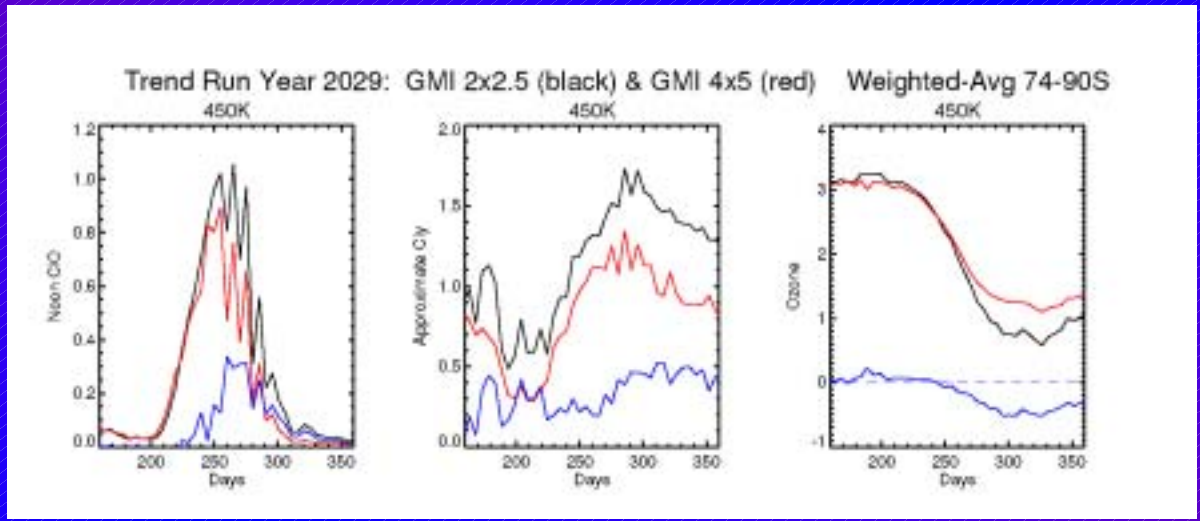
Horizontal Sensitivity: Cl in the Vortex

2x2.5° = black

4x5° = red

Blue Line:

2x2.5° minus 4x5°



- 2x2.5° has higher ClO in the vortex during Sept and Oct
- "Approx. Cl_y" (= ClNO3 + HCl + noon ClO) is higher all winter and spring at 2x2.5°
- O_3 loss is more rapid in Sept and continues into Oct, in better agreement with MLS

Sensitivity to Advection Core: GSFC vs. GMI versions of TPCORE

- Why? Previous GSFC-CTM simulations got higher transport grades. Was it the CTM or just the different year of FVGCM winds used?
- GSFC-CTM horizontal sensitivity tests – again, with different FVGCM winds – did not indicate such a strong sensitivity to horizontal resolution
- To test this sensitivity, FVGCM winds from same year (from the Trend run) at 4x5^{o} x 28 level resolution were run for 1 year
- GSFC-CTM has age tracer + param chem for CH_4

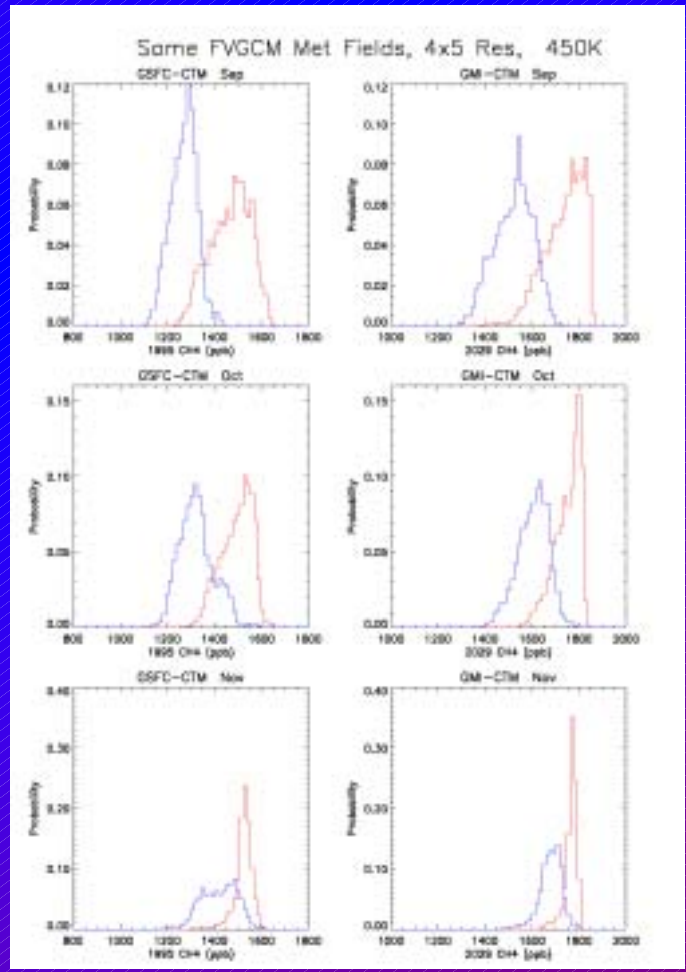
4x5° TPCORE Sensitivity: Antarctic Vortex Edge

Although GMI uses full chemistry and 2029 CH4 at the surface, both simulations do an equally poor job of representing of the vortex mixing barrier.

This is reassuring.

60-80°S PDF in blue

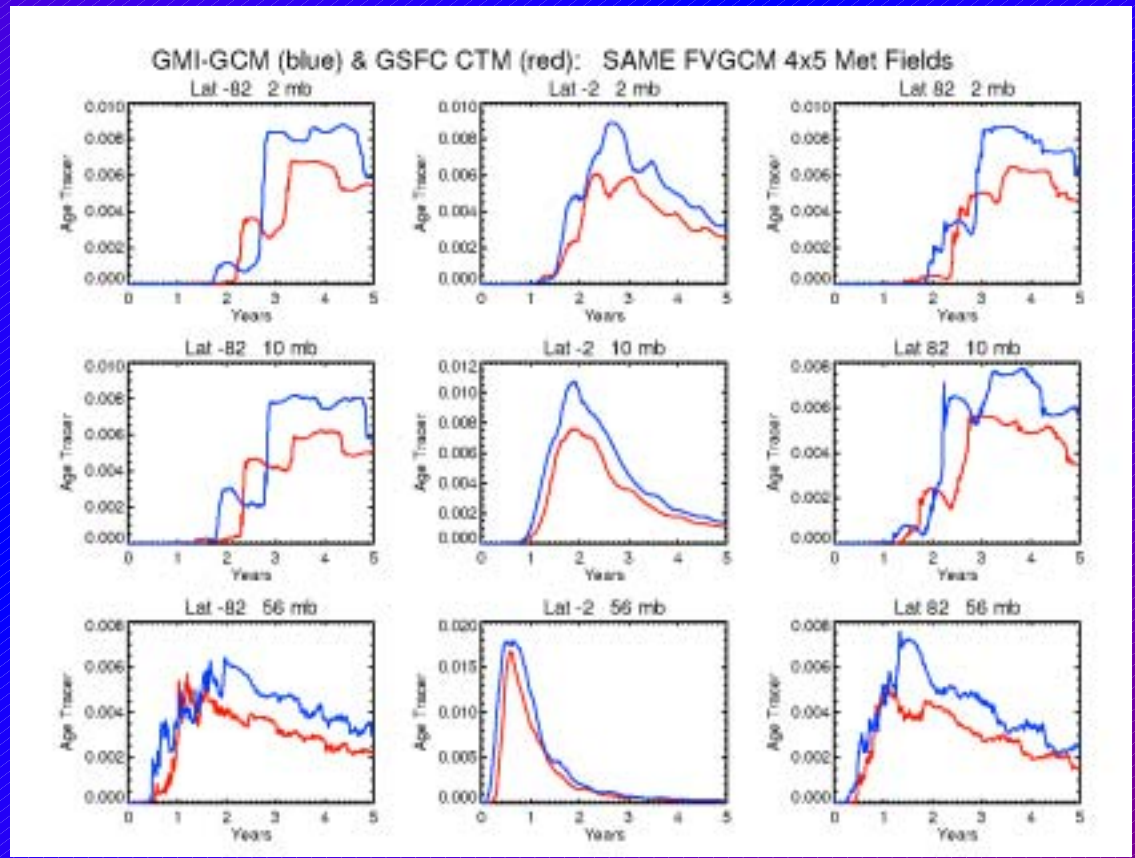
40-60°S PDF in red



GSFC **GMI**

4x5° TPCORE Differences: Age Spectra

- Age tracer is sensitive to small differences in transport.
- At all locations shown, GMI-CTM (blue) air arrives sooner than the GSFC-CTM (red).
- Younger air is (usually) not better.



GSFC and GMI TPCORE Differences?

GSFC-CTM: Sensitivity to Vertical Resolution and Lid

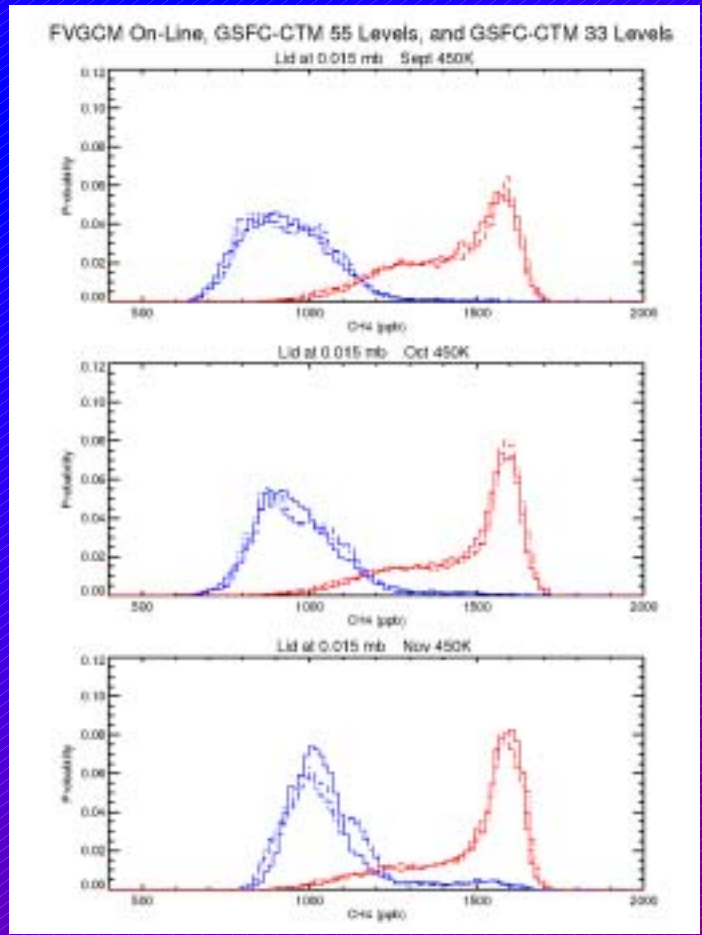
- A series of experiments were done with the GSFC-CTM using 5-yrs of FVGCM met fields, parameterized CH_4, and age tracer.
- The original FVGCM fields at 2x2.5° with 55 levels up to 0.015 hPa.
- The experiments evaluate these implementations:
  - Online vs. Offline Transport (no change to met fields)
  - Vertical Res: 55 levels vs. 33 levels (same top level)
  - Model Lid: 33 levs (lid=0.015 hPa) vs. 28 levs (lid=0.4 hPa)

GSFC-CTM experiments with a 0.015 hPa lid: Antarctic Vortex Behavior

60-80°S PDF in blue 40-60°S PDF in red

The online FVGCM, offline 55 level, and offline 33 level results are superimposed: they are nearly identical!

The 33 level CTM uses the same levels as the 28 level model from the surface to 1.3 hPa, but has 6 mesospheric levels and a lid at 0.015 mb.



GSFC-CTM experiments with a 0.015 hPa Lid: Age Spectra

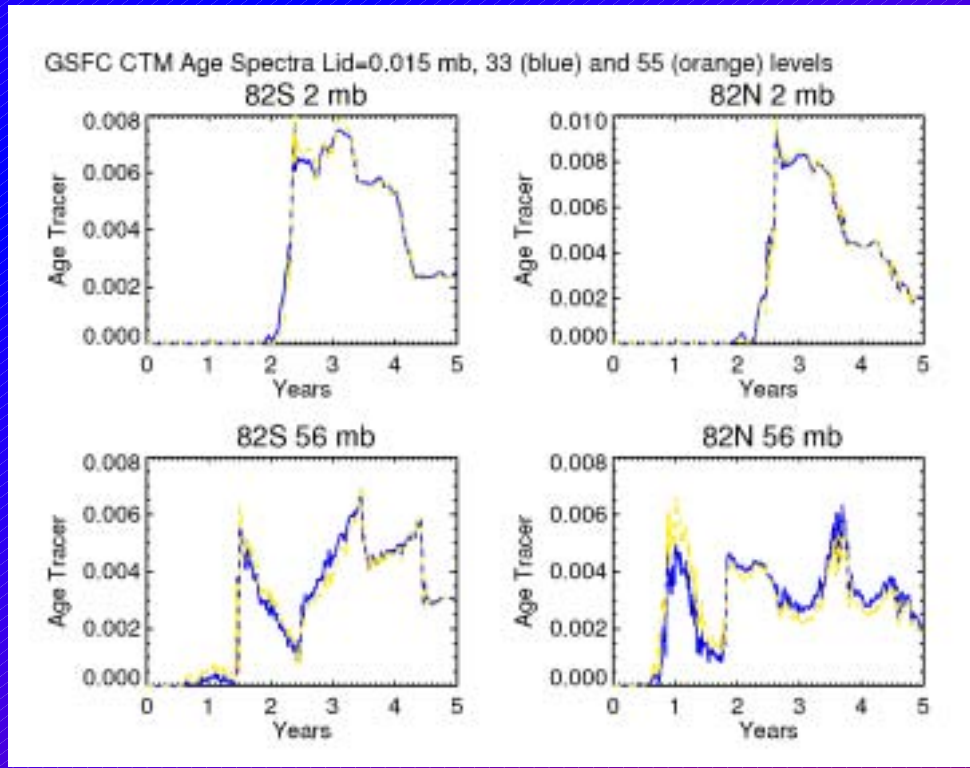
The 55 level CTM has 24 strat levels and 14 mesospheric levels, lid at 0.015 hPa.

The 33 level CTM has 15 strat levels and 6 mesospheric levels, lid at 0.015 hPa.

Their age spectra are nearly identical throughout the stratosphere.

33 Level CTM (blue)

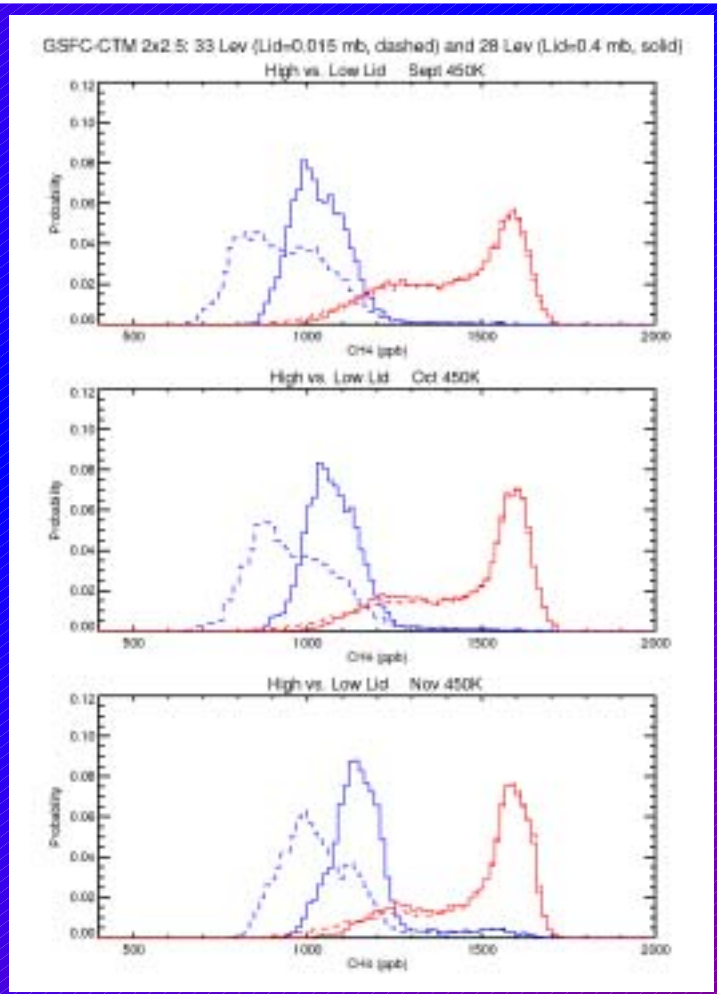
55 level CTM (orange)



GSFC-CTM experiments: High vs. Low Lid Antarctic vortex behavior

60-80°S PDF in blue 40-60°S PDF in red

- The differences are in the high latitude distributions
- Vortex CH_4 is lower (more like HALOE) in the high lid model
- A good barrier to mixing is maintained in both models



Dashed lines = 0.015 hPa Lid

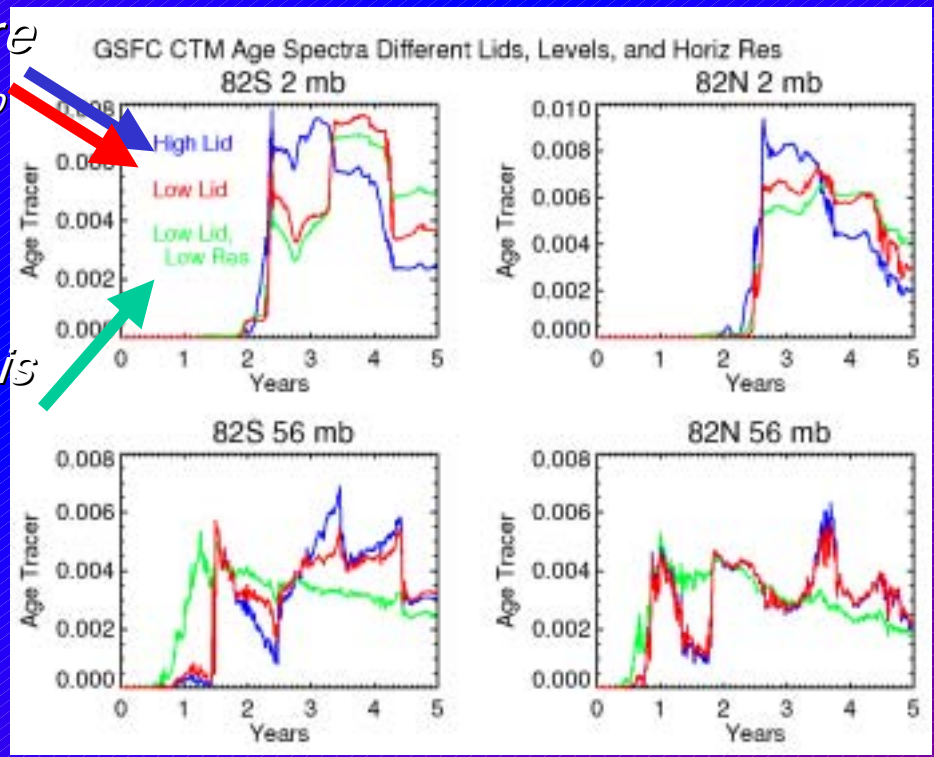
Solid lines = 0.4 hPa Lid

GSFC-CTM experiments :
Age Spectra of High Lid, Low Lid, and Low Lid Low Res

- In the upper stratosphere, lid height affects transport more than horiz resolution.
- In the lower stratosphere, horizontal resolution affects transport more than lid height.

Both are 2x2.5°

Green is 4x5°

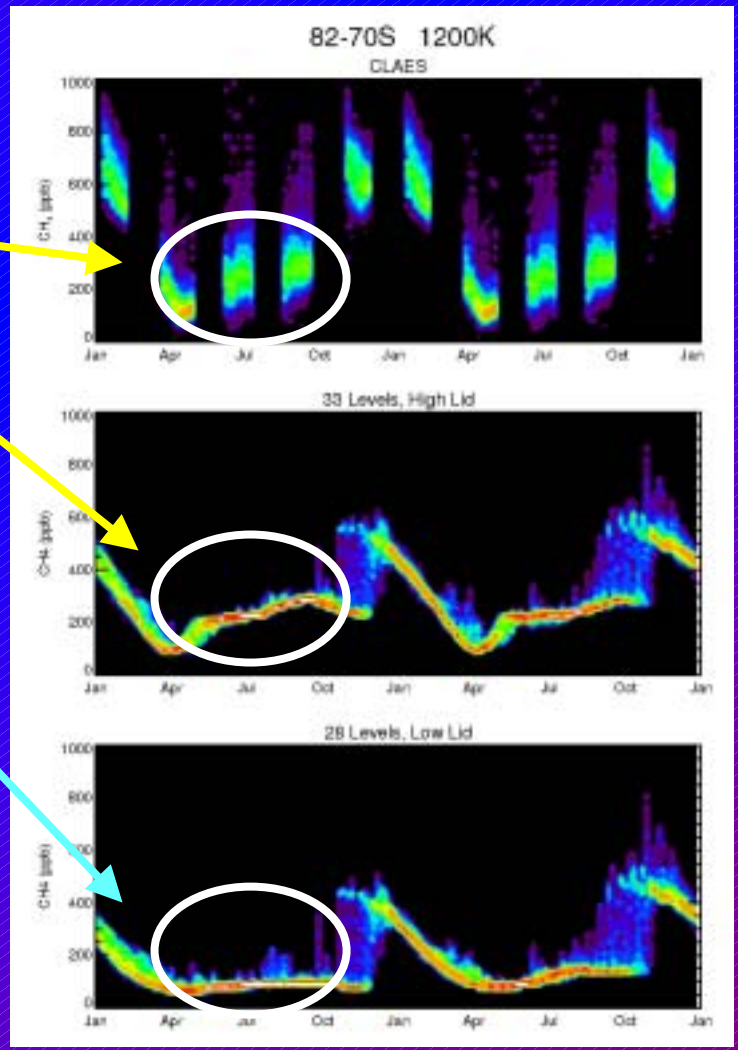


But how do we know whether the high lid age spectra are better than the others?

GSFC-CTM experiments: High vs. Low Lid

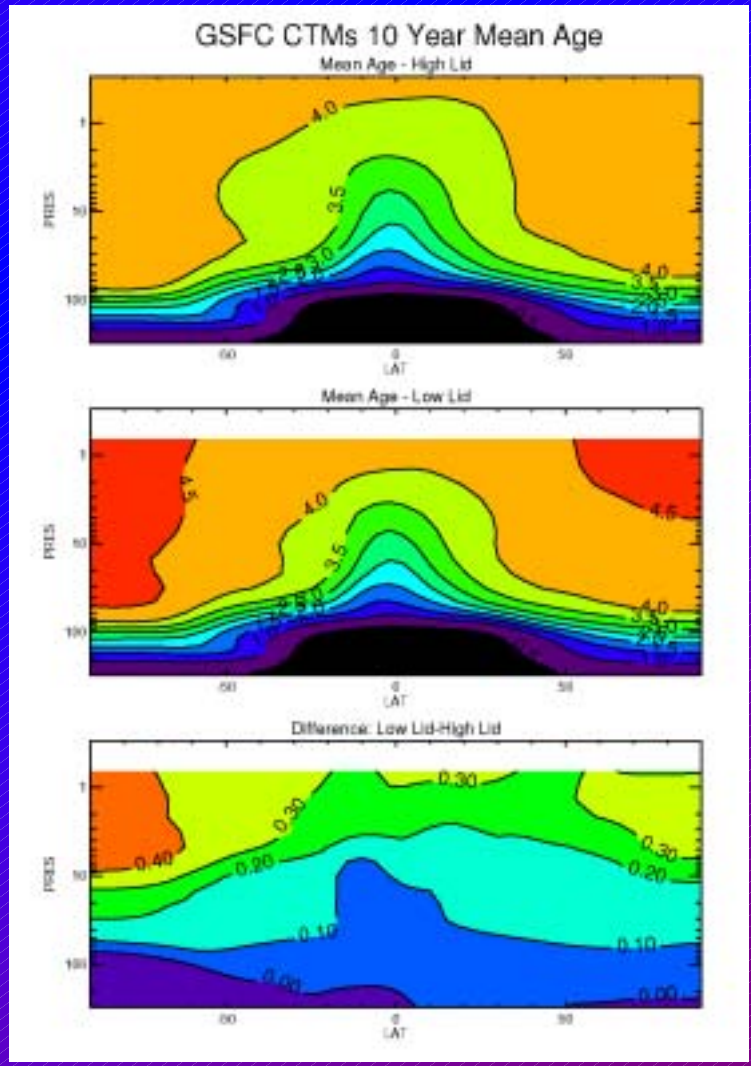
Extratropical CH_4 annual cycle in the upper stratosphere

- High lid model (middle) and CLAES (top) show increasing CH_4 in austral fall and winter.
- Low lid model (bottom) shows flat CH_4 in fall and winter, indicating a lack of transport from low latitudes.
- Upper stratospheric transport from tropics to pole is better with a high lid.



GSFC-CTM experiments: High vs. Low Lid
Mean Age – a counterintuitive result!

- The high lid model (top) has younger mean age than the low lid model (middle).
- Tropical air seems to be 'trapped' (I.e., lacks PW forcing?) and can't get to the polar region.
- The low lid model has older polar stratospheric air, ***but for the wrong reasons!***



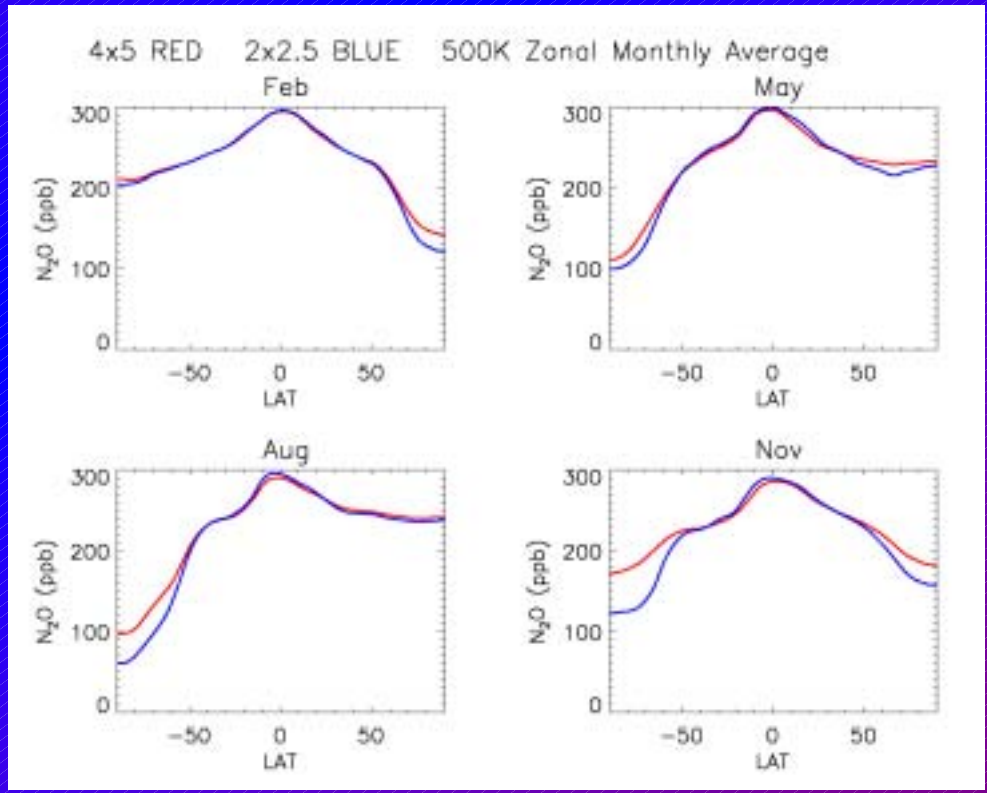
Conclusions: What changes should we make to the GMI Model?

- **Use 2x2.5° resolution** – It improves vortex edge and LS meridional gradients ('N_2O test', not shown), maintains higher ClO and Cl_y in vortex, allowing faster and later O_3 loss. David's paper showed these deficiencies in the 4x5° simulations.
- **Add 5 vertical levels and move the lid higher** (0.015 hPa for FVGCM). This improves the realism of the middle and upper stratospheric circulation.
  - *For UT/LS experiments, do we really need to do the mesospheric chemistry correctly, (I.e., add new photolytic reactions and Lyman alpha)?.*
- **Update our version of TPCORE?** We may want to do an age tracer expt with GMI at 2x2.5° to verify GSFC/GMI differences found at 4x5°.

Sensitivity to Horizontal Resolution : N_2O vs. Latitude in the Lower Stratosphere

500K

- Higher resolution has the greatest effect in polar regions.
- By the 2nd month of the 2x2.5° simulation (Feb), lower N_2O is already seen in the Arctic
- Huge differences in the Antarctic. Not surprising considering the results of the HALOE CH_4 test.



2x2.5° (blue) *4x5° (red)*

TPCORE Sensitivity: K-ord (vertical diffusivity)

- These experiments were done with the GSFC-CTM at 2x2.5^{o} with 'Trend run' winds.
- At 2x2.5^{o}, the CTM shows a slight sensitivity to k-ord.
- GMI tpcore used k-ord=? (and 4x5^{o} winds)
- Would there be more sensitivity at 4x5^{o}???

k-ord=7 (blue) ***k-ord=4 (red)***